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Bilateral and Unilateral Asymmetries of Strength and Flexibility in Young Elite Sailors: Windsurfing, Optimist and Laser Classes

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Abstract: In sport sailing, performance is related to the sailor's ability to maintain the stability of the boat, and the boat class determines the variables involved in such ability. In monohull-type vessels, such as the Optimist and Laser classes, the flexibility of the hip joint is a key performance factor. In the Windsurfing class, performance is determined by the strength of the flexors of the fingers and elbows. The performance of the sailor may be affected by asymmetries in the strength and flexibility of the muscles and joints involved in technical actions. The objective of this study was to evaluate asymmetries in strength and flexibility in young sailors. Thirty-three young sailors (ten girls) from the Windsurfing, Optimist and Laser classes were assessed for manual strength and flexibility, by dynamometry and straight leg lift tests, respectively. The symmetry index and the functional asymmetry of compression force were calculated. The results showed no differences between sailors according to gender. The sailors of the Laser class obtained the highest levels of manual strength, whereas those of the Windsurfing class showed the highest flexibility levels. The girls' group and Windsurfing class had the highest percentage of sailors with strength asymmetry, whereas, the sailors of the Optimist class presented a greater percentage of asymmetry in flexibility. There were no differences in upper limb strength and lower limb flexibility between the dominant and non-dominant sides.

Keywords: asymmetry; sport sailing; strength; flexibility

1. Introduction

Performance in sport sailing is directly related to the sailor's ability to overcome the external forces produced by the boat and maintain the stability of the boat [1].

In monohull-type vessels, such as those belonging to the Optimist and Laser classes, the stability of the vessel is conditioned by the time taken by the sailor to perform the maneuvers. If such time increases, the time required to stabilize the boat also increases, which reduces its speed and, therefore, the sailor's performance [2]. Having greater flexibility in the hip joint could allow the sailor to carry out the maneuvers with greater efficiency in this type of boats, thus decreasing the impact on the stability of the boat [3]. It is worth highlighting the importance of the flexion capacity of the hip joint as a performance variable in sport sailing, specifically the elongation of the hamstring musculature.

On the other hand, in Windsurfing class boats, the strength of the upper limbs is directly related to the sailor's performance [4]. With the action of the flexors of the fingers, together with the that of the flexors of the elbows, the sailor controls the boat sail, which controls the direction and speed of the vessel [5,6].

Body movements can be adversely affected by asymmetries between the strength and flexibility of the joints or limbs [7,8]. Functional evaluation can be used to identify and assess any asymmetry in athletes. The straight leg lift test (SLL) and the handgrip strength test are easy and practical tests to perform a functional evaluation [9–12]. For the evaluation of body asymmetry in athletes, the so-called symmetry index is used. This index has been used mainly to compare the symmetry between the right and left side of the body and between the upper and lower limbs, and in sports where body performance is determined by the use of the upper and lower limbs unilaterally and bilaterally [13–16]. The symmetry index is the most important parameter when evaluating functional asymmetries in athletes of different disciplines [17].

To our knowledge, there are no studies in the literature focused on strength and flexibility asymmetry in sport sailors. Therefore, the aim of the present study was to investigate unilateral and bilateral asymmetries in strength and flexibility in young elite sailors.

2. Material and Methods

2.1. Participants

Thirty-three young Spanish elite sailors (10 girls and 23 boys) from the Windsurfing (n = 10), Optimist (n = 16) and Laser (n = 7) classes, in the age range of 12–16 years participated in this study. The parents and coaches of the sailors were contacted by email to send them a document explaining the objectives and characteristics of the study. All sailors participated voluntarily, for which they were requested to sign an informed consent. The requirements of the Declaration of Helsinki (1964) and the ethical standards in sport and exercise research were followed throughout the entire research.

2.2. Hand Dynamometry

To perform the test, the subject stood on his/her feet, with his/her arms extended and parallel to the trunk, held the dynamometer with one hand and exerted maximum strength for two seconds. Two attempts were made with each hand, and the better of those two attempts was recorded. After five seconds of rest, the subject repeated the test with the other hand [18]. Before the test was run, the subject was allowed to familiarize with the dynamometer.

A manual dynamometer (Computational Bio-Systems, SL brand, produced by TAKEI), was used to measure the manual compression force of the participants, expressed in kg, in a range of 0 to 100 kg, with 1 kg being the minimum unit of measure.

2.3. Straight Leg Lift Test (SLL)

The athlete lay in the supine position, with his/her legs extended and his/her hip in a neutral position (respecting the natural curvature of the lower back). The examiner slowly flexed one of the legs, holding the foot by the heel, until the subject reported pain in the back of the thigh or until retroversion appeared in the pelvis. The other leg remained extended. Once the maximum leg height was reached, the goniometer was placed at the head of the femur and one of the goniometer arms was placed parallel to the ground, while the other one was placed in the direction of the fibula malleolar. This was performed on both legs (Ramos, González and Mora, 2007).

In the evaluation of the angles, normality was considered at 75° and above, whereas grade I and grade II shortening were considered at 74–61° and 60° and below, respectively [19].

To measure the angulation, an extendable branch goniometer (Lafayette Instrument Co., Inc., Sagamore Pkwy N, Lafayette, USA, Model 01135) was used. The measurements were expressed in degrees, in a range of 0°–180°, with 1 degree being the minimum unit of measure.

2.4. Symmetry Index (SI)

The asymmetry in strength and flexibility was quantified using the following formula [20]:

$$SI = \frac{Xr - Xl}{\frac{1}{2}(Xr + Xl)} \times 100\%$$

In this formula, "Xr" is the value for the right side and "Xl" for the left side. The zero value of SI indicates that the subject has perfect symmetry in the analyzed joints. A positive value of SI indicates that "Xr" is greater than "Xl", and a negative value indicates that "Xr" is lower than "Xl" [21]. Asymmetry is considered when SI is greater than 10 percent [22].

2.5. Functional Asymmetry of Compression Force (FACF)

The functional asymmetry of compression force was calculated using the following formula [23]:

$$Kas = \frac{Er - El}{Er + El}$$

In this formula, "Kas" is the asymmetry coefficient, "Er" is the right hand´s compression force, and "El" is the left hand´s compression force. A positive value of "Kas" indicates the dominance of right reactions and a negative value indicates the dominance of left reactions.

2.6. Statistical Analyses

The data are presented as means and standard deviations. The level of significance was set at $p < 0.05$. For the statistical analyses, the statistical package SPSS v20.0 (SPSS Lead Technologies Inc., Chicago, IL, USA) was used. The data were subjected to a descriptive analysis and inferences, and their normality was verified using the Kolmogorov-Smirnov test. Counts (frequencies) and proportions were calculated for all the data. Due to the measurement levels of the data, a non-parametric Kruskal-Wallis ANOVA test was applied to establish differences between the Windsurfing, Optimist and Laser class groups. Within each class and among them, an analysis according to gender was not carried out, since the sample of girls was not representative, although it was conducted to evaluate the total sample of sailors. The Windsurfing class group was the only one that presented a similar sample of boys and girls (5 boys, 5 girls), while in the Optimist class there were 3 girls and 12 boys, and the Laser class group had 2 girls and 5 boys. For this reason, it was decided to carry out the analysis including boys and girls in each of the sailing classes.

3. Results

Table 1 shows the results of the descriptive analysis of the total sample and by gender. The analysis of the mean values did not show differences in the variables according to gender.

Table 1. Mean ± SD of the variables analyzed in the total sample of sailors and by gender.

	All (n = 33)	Girls (n = 10)	Boys (n = 23)
Age (years)	13.7 ± 1.3 (12–16)	13.7 ± 1.4 (12–16)	13.2 ± 1.2 (12–16)
Height (cm)	160.3 ± 9.6 (146–197.5)	154.4 ± 4.8 (151.5–165.5)	161.3 ± 10.9 (146–179.5)
Weight (kg)	51.7 ± 10.2 (35.5–72.2)	51.7 ± 8.2 (35.5–64)	51.7 ± 11.1 (36.5–72.2)
Right hand dynamometry (kg)	28.2 ± 8 (18–51)	24.8 ± 5.3 (18–35)	29.8 ± 8.6 (19–51)
Left hand dynamometry (kg)	27.1 ± 7.2 (15–45)	24.4 ± 4.5 (18–30)	28.6 ± 7.9 (15–45)
Dominant hand dynamometry (kg)	29.1 ± 7.9 (18–51)	26.1 ± 5.1 (18–35)	30.4 ± 8.6 (19–51)
Non-dominant hand dynamometry (kg)	26.3 ± 7.1 (15–45)	23.1 ± 4.2 (18–30)	27.1 ± 7.7 (15–45)
Hand dynamometry SI (%)	4.2 ± 11.9 (−29.8–27)	1.1 ± 15.6 (−29.8–15.4)	5.6 ± 10 (−10.8–27)
Asymmetry coefficient (kg)	0.02 ± 0.05 (−0.14–0.13)	0.005 ± 0.07 (−0.14–0.07)	0.02 ± 0.05 (−0.05–0.13)
Right SLL test (°)	85.8 ± 8.9 (68–100)	90.4 ± 7.4 (77–100)	83.8 ± 9 (68–100)
Left SLL test (°)	84.1 ± 8.3 (63–99)	86.8 ± 7.7 (74–99)	82.9 ± 8.4 (63–99)
Dominant SLL test (°)	87.5 ± 8.1 (69–100)	91.2 ± 7.3 (77–100)	85.9 ± 8.1 (69–100)
Non-dominant SLL test (°)	82.4 ± 8.4 (63–98)	86 ± 7.2 (74–95)	80.8 ± 8.5 (63–98)
SLL test SI (%)	2.01 ± 8.1 (−20.4–21.3)	4.11 ± 6.6 (−4.8–16.2)	1.1 ± 8.6 (−20.4–21.3)

Note: $p < 0.05$; (minimum–maximum).

Table 2 shows the descriptive analysis for each of the groups of sailors. It is observed that the sailors of the Laser class had greater age than those in the Optimist ($p < 0.01$) and Windsurfing ($p < 0.01$) groups, and greater weight than in the Optimist group ($p < 0.01$). The Windsurfing class had greater weight than the Optimist group ($p < 0.01$). The height of the athletes in the Optimist class was lower than that of those in the Windsurfing ($p < 0.05$) and Laser classes ($p < 0.01$), and no differences were found between the latter two classes for this variable. The results of the right hand dynamometry test show that the Laser class had a higher compression force, although only compared to the Optimist class group ($p < 0.01$), since this difference was not significant with respect to the Windsurfing class group. Regarding the left hand, the Laser class obtained higher results compared to the Optimist class group ($p < 0.01$) (Table 2). With regard to the flexibility of the ischiosural musculature, the values of the sailors of the Windsurfing class were only greater than those of the Laser class ($p < 0.05$; $p < 0.05$, right and left, respectively), since the differences with the Optimist class group were not significant. No differences were found when comparing the symmetry indices and the values of functional asymmetry of compression force and flexibility between the three class groups. When comparing the dominant side of hand dynamometry between the three groups, we observed that the Laser class group had greater strength compared to the Optimist class group ($p < 0.01$). The same situation occurred when the non-dominant side of hand dynamometry was compared ($p < 0.01$). In the SLL test, the Windsurfing class group had greater flexibility in the dominant leg compared to the Laser class group ($p < 0.01$).

Table 2. Mean ± SD of the variables analyzed in the groups of Windsurfing, Optimist and Laser.

	Windsurfing (n = 10)	**Optimist (n = 16)**	**Laser (n = 7)**
Age (years)	13.7 ± 1.1 (12–15)	13 ± 0.6 (12–14)	15.7 ± 0.4 ** (15–16)
Height (cm)	163.6 ± 8.2 * (151.5–179.5)	153.7 ± 6.2 (146–166)	170.5 ± 6 ** (162–178)
Weight (kg)	55.4 ± 6.1 ** (47.7–65)	43.5 ± 5.2 (35.5–52.1)	65.2 ± 4.3 ** (60.6–72.2)
Right hand dynamometry (kg)	28.9 ± 8.8 (20–44)	24.3 ± 4.7 (18–34)	36.6 ± 6.9 ** (29.5–51)
Left hand dynamometry (kg)	28.2 ± 6.6 (19–40)	22.8 ± 4.4 (15–32)	35.2 ± 6.2 ** (30–45)
Dominant hand dynamometry (kg)	30.4 ± 8 (21–44)	24.6 ± 4.5 (18–34)	37.5 ± 7 ** (30–51)
Non-dominant hand dynamometry (kg)	26.7 ± 7.1 (19–40)	22.5 ± 4.4 (15–32)	34.3 ± 5.8 ** (29.5–45)
Hand dynamometry SI (%)	1 ± 16.9 (−29.8–27)	6.5 ± 9 (−9.5–23.5)	3.7 ± 9.7 (−10.8–15.4)
Asymmetry coefficient (kg)	0.00 ± 0.08 (−0.14–0.13)	0.03 ± 0.04 (−0.04–0.11)	0.01 ± 0.04 (−0.05–0.07)
Right SLL test (°)	91.2 ± 8.1* (80–100)	85.1 8 ± 8.8 (68–95)	79.7 ± 6.4 (73–89)
Left SLL test (°)	89.1 ± 6.4* (80–99)	83.2 ± 9 (63–99)	78.8 ± 5.1 (72–85)
Dominant SLL test (°)	92.6 ± 7 ** (80–100)	87.1 ± 7.9 (69–99)	81 ± 5.8 (75–89)
Non-dominant SLL test (°)	87.7 ± 6.9 (80–98)	81.2 ± 8.9 (63–95)	77.5 ± 5.2 (72–85)
SLL test SI (%)	2.2 ± 7.5 (−9.3–16.2)	2.3 ± 9.6 (−20.4–21.3)	0.9 ± 5.2 (−8.9–5.8)

Note: * $p < 0.05$; ** $p < 0.01$; (minimum–maximum).

No significant differences were observed when comparing the dominant side with the non-dominant side in each of the groups analyzed (Table 3).

Table 3. Comparison between the dominant and non-dominant side for hand dynamometry and SLL test (mean ± SD).

	Dominant Hand Dynamometry (kg)	**Non-Dominant Hand Dynamometry (kg)**	**Dominant SLL Test (°)**	**Non-Dominant SLL Test (°)**
All (n = 33)	29.1 ± 7.9 (18–51)	26.3 ± 7.1 (15–45)	87.5 ± 8.1 (69–100)	82.4 ± 8.4 (63–98)
Girls (n = 10)	26.1 ± 5.1 (18–35)	23.1 ± 4.2 (18–30)	91.2 ± 7.3 (77–100)	86 ± 7.2 (74–95)
Boys (n = 23)	30.4 ± 8.6 (19–51)	27.1 ± 7.7 (15–45)	85.9 ± 8.1 (69–100)	80.8 ± 8.5 (63–98)
Windsurfing (n = 10)	30.4 ± 8 (21–44)	26.7 ± 7.1 (19–40)	92.6 ± 7 (80–100)	87.7 ± 6.9 (80–98)
Optimist (n = 16)	24.6 ± 4.5 (18–34)	22.5 ± 4.4 (15–32)	87.1 ± 7.9 (69–99)	81.2 ± 8.9 (63–95)
Laser (n = 7)	37.5 ± 7 (30–51)	34.3 ± 5.8 (29.5–45)	81 ± 5.8 (75–89)	77.5 ± 5.2 (72–85)

Note: $p < 0.05$; (minimum–maximum).

Table 4 shows the percentage of sailors who had positive or negative asymmetry according to the SI and Kas values obtained. When comparing the total sample of sailors (i.e., the three classes together) by gender, it was observed that the group of girls had a greater percentage of asymmetries in hand dynamometry than the boys. When analyzing the values of Kas in this variable for these groups, it was verified that the right side prevailed as dominant for both groups. Regarding SLL, boys and girls showed similar values in asymmetry (21.5% versus 20%). The analysis between the different classes reflects that half of the sailors of the Windsurfing class had asymmetry in hand dynamometry, and that the right hand was the dominant one in the three groups. The values in SLL indicate that the Optimist class had the highest percentage of sailors with asymmetry (32.6%), while in the Laser class there were no sailors with asymmetry.

Table 4. Percentages of sailors presenting asymmetry in the sample by gender and class according to the SI and Kas values.

	All	Girls	Boys	Windsurf	Optimist	Laser
Positive hand dynamometry SI	33%	40%	34.4%	30%	37.8%	28.6%
Negative hand dynamometry SI	12%	20%	8.6%	20%	0%	14.3%
Total hand dynamometry SI	45%	60%	43%	50%	37.8%	42.9%
Positive Kas	63.9%	70%	69.9%	60%	81.8%	57.2%
Negative Kas	36.1%	30%	30.1%	40%	18.2%	42.8%
Positive SLL SI	15%	20%	12.9%	20%	20%	0%
Negative SLL SI	6%	0%	8.6%	0%	12.6%	0%
Total SLL SI	21%	20%	21.5%	20%	32.6%	0%

The results obtained in the SLL test for the right and left leg indicate that, in the total sample of sailors, only 9% had grade I shortening in the right leg and 12% in the left leg (Figure 1). This shortening is present in the group of boys and with a percentage of 12% in both legs. In the different classes evaluated in the study, we observed that 100% of the sailors of the Windsurfing class had normal flexibility in both legs, while in the Laser class 28.6% had grade I shortening in the right leg and 14.3% in the left leg, with this class being the one with the greatest number of sailors with shortening. In the Optimist class, only 12.5% and 12.6% had grade I shortening in the right and left leg, respectively.

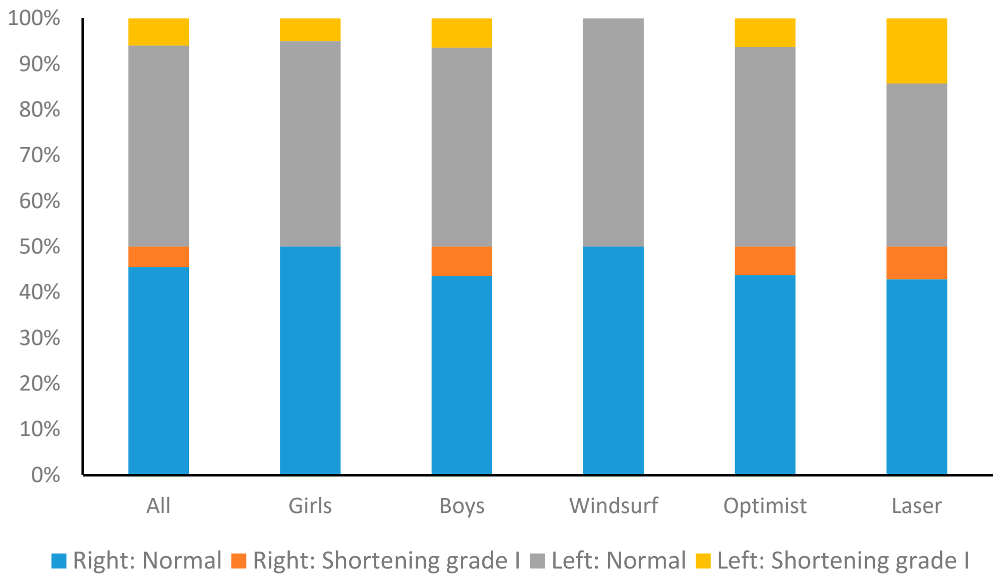

Figure 1. Percentage of sailors presenting normal flexibility or grade I shortening in the right and left leg.

4. Discussion

The results of the strength and flexibility tests did not show significant differences between boys and girls (Table 1). Similarly, no differences were found when comparing the age of the sailors. It must be taken into account that the evolution of strength is related to age, and it is from the age of 10 when boys present improvements with respect to girls, although other studies state that it is from the age of 12 when these differences are more noticeable, mainly due to the greater development of musculoskeletal structures in boys [24]. In our case, the age of the sailors was between 12 and 16 years, thus it would be logical to find differences between them in the manual dynamometry test. The absence of differences in age and the lower number of female sailors could explain these results.

Regarding flexibility, studies show that it increases with age in boys and remains stable until the age of 14–15 years in girls. Therefore, and based on this, it would have been expectable to find differences in the SLL test between boys and girls. We attribute this circumstance to the same reason defined for the hand strength tests [25]. The results in manual grip strength values were much lower compared to another study in elite sailors in the Optimist (31.4 ± 4 vs. 24.3 ± 4.7; 31.4 ± 4 vs. 22.8 ± 4.4) and Laser (54.6 ± 3.6 vs. 36.6 ± 6.9; 54.6 ± 3.6 vs. 35.2 ± 6.2) classes [26]. It must be taken into account that this study presents the average value of the right and left hand, and that the average age of the Optimist and Laser class groups was 12.3 ± 1.4 and 16.5 ± 1.6 years, respectively.

Regarding the differences between classes, we observed that the Laser class had a higher average value in the manual dynamometry test, for both the left and right hand and for the dominant and non-dominant hand. The age of these sailors was higher than those of the Optimist and Windsurfing classes, thus the greater value in the levels of strength could be related to a greater development of skeletal muscle structures (Table 2). Despite this age difference, it would be expected of the sailors of the Windsurfing class to present greater strength values in the hand grip test due to the improvements acquired by the specific practice of their sport [4–6]. In flexibility, only the sailors of the Windsurfing class had better results than those of the Laser class (Table 2). The younger age of the sailors of the Windsurfing group could benefit them in terms of the evolution of flexibility with age, since the flexibility of the hip joint has a positive development up to the age of 8–9 years; unless it is trained, such flexibility decreases from that age [27].

No differences were found when comparing the average values of manual strength and hip flexibility between the dominant and non-dominant sides, neither for the total sample nor by gender or class (Table 3). Similarly, no lateral differences were found between genders (Table 1) in the force of manual dynamometry of the dominant and non-dominant sides, which is in line with other studies of similar characteristics [28,29]. Although in our case we did not find differences in bilateral asymmetry, previous studies show that this asymmetry increases with age and that it is more pronounced during the adolescence period [30]. This lack of asymmetry variability in the hand force in our study may due to factors such as the level of general physical condition and the type of occupation.

In our sample, 70% of the sailors were right-handed. This circumstance is consistent with most studies found in the literature, which report that the dominant side of the upper limbs is usually the right side [30]. In our study, regarding the lower limbs, 67% were right-handed. In the total sample, 70% and 80% were right-handed for the upper and lower limbs, respectively. In manual dynamometry, with respect to the different classes, 60%, 79% and 47% of the sailors were right-handed in the Windsurfing, Optimist and Laser classes, respectively. The percentages of sailors with dominant right side in the Windsurfing, Optimist and Laser classes in the lower limbs were 60%, 69% and 72%, respectively.

Table 4 shows the percentage of sailors for each of the analyzed variables. The Windsurfing class had the highest percentage of subjects with asymmetry in hand grip strength compared to the other classes. It would have been very interesting to be able to analyze the effect of years of navigation experience on the presence of asymmetry in strength and flexibility. In this way, it would be possible to explain whether the continued practice in each of the classes influences the appearance of a greater or lesser percentage of asymmetry.

Figure 1 shows that the sailors in our study had no significant shortening of the ischiocrural musculature, since the presence of grade I shortening was below 15% in most of them. Only in the Laser class, and for the left leg, the percentage of sailors presenting this type of pathology was 29%.

In our study, we encountered several limitations. The first limitation was the small sample size. Having a more representative sample would have allowed us to draw more precise conclusions, and a more balanced sample in terms of gender would have allowed comparing boys and girls in each of the class groups. It would have also been interesting to evaluate other variables through functional tests of strength and flexibility in order to compare the results obtained. Knowing the experience of the sailors would allow categorizing the participants and determining whether this variable affects the appearance of asymmetries due to sports practice.

We must emphasize that this study is the first to evaluate the asymmetries in strength and flexibility in sport sailing.

5. Conclusions

There were no significant differences in the levels of strength and flexibility between male and female sailors. The sailors of the Laser class had higher levels of strength in hand grip, while those of the Windsurfing class had the greatest hip joint flexibility. There were no differences in upper limb strength and lower limb flexibility between the dominant and non-dominant sides. The group of girls showed a higher percentage of sailors with asymmetry in hand grip force. The highest levels of asymmetry in strength and flexibility were obtained by the Windsurfing class and the Optimist class, respectively. Only a percentage of sailors below 15% had grade I shortening in the hamstring muscles.

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